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Motivation: key to a healthy lifestyle in people with diabetes? Current and emerging knowledge and applications

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What's new?

- A healthy lifestyle is important for all people with diabetes, and motivation is an underlying determinant of lifestyle behaviours.
- Motivation is, in turn, shaped by a complex interaction of factors at the psychological, neuro-biological and environmental levels.
- Effective approaches to alter motivations have been identified at various levels thus far, but more research is required to inform (clinical) practice and generate lasting and meaningful motivational changes in individuals and populations with diabetes or an increased risk thereof.

Abstract

Aim Motivation to take up and maintain a healthy lifestyle is key to diabetes prevention and management. Motivations are driven by factors on the psychological, biological and environmental levels, which have each been studied extensively in various lines of research over the past 25 years. Here, we analyse and reflect on current and emerging knowledge on motivation in relation to lifestyle behaviours, with a focus on people with diabetes or obesity. Structured according to psychological, (neuro-)biological and broader environmental levels, we provide a scoping review of the literature and highlight frameworks used to structure motivational concepts. Results are then put in perspective of applicability in (clinical) practice.

Results Over the past 25 years, research focusing on motivation has grown exponentially. Social–cognitive and self-determination theories have driven research on the key motivational concepts 'self-efficacy' and 'self-determination'. Neuro-cognitive research has provided insights in the processes that are involved across various layers of a complex cortical network of motivation, reward and cognitive control. On an environmental – more upstream – level, motivations are influenced by characteristics in the built, social, economic and policy environments at various scales, which have provided entry points for environmental approaches influencing behaviour.

Conclusions Current evidence shows that motivation is strongly related to a person's self-efficacy and capability to initiate and maintain healthy choices, and to a health climate that supports autonomous choices. Some approaches targeting motivations have been shown to be promising, but more research is warranted to sustainably reduce the burden of diabetes in individuals and populations.

<H1>Introduction

Maintaining a healthy lifestyle with sufficient physical activity, healthy dietary behaviours and limited sedentary (sitting) time is important for successful self-management by all people with diabetes. However, many people with – and also those without – diabetes find it difficult to adopt and maintain a healthy lifestyle. It is thought that motivation plays a large role, and that if people with diabetes were motivated to sustainably engage in healthy lifestyle behaviour, this would be a simple and effective way to reduce diabetes incidence as well as diabetes-related complications. But motivation is not easy to change.

Motivation can be defined as the process that initiates, guides and maintains goal-oriented behaviours. In this paper, we analyse motivation in relation to lifestyle behaviours in people with diabetes or risk thereof. We focus on the past, present and future, and consider how this knowledge translates into clinical practice. We review the psychological models that drove early work on this topic and the evidence that was accumulated through related research. We also examine recent developments in biological and socio-environmental factors affecting motivation. Our goal is not to further develop these models, but rather to consider their clinical implications, especially as they can provide guidance to providers in their routine clinical practice.

<H1>What we knew in 1995

Efforts to analyse motivation within diabetes-related settings were scarce until the 1990s when more research became available. Although there are many conceptualizations of motivation traditionally ranging from need-based models [1] to expectancy theories [2], the conceptualizations from 25 years ago defined motivation as encompassing self-regulatory processes involving the selection, activation and sustained direction of behaviour towards certain goals [3]. Since then, two dominant behaviour change theories have developed that incorporate motivation: socio-cognitive theory [4] and self-determination theory [5]. However, there was evidence that better diabetes self-management was associated with fewer social and environmental barriers (see Supporting Information [S34,S35]).

<H2>Social cognitive theory

Social cognitive theory is a learning theory based on the idea that people learn by observing others [4]. A key element of social cognitive theory is the concept of, which was defined in 1997 as a person’s judgement of the ability to produce specific actions [3]. Self-efficacy contributes to motivation by shaping goals and aspirations, the amount of effort and perseverance spent to attain to a set goal, and by shaping the outcomes one can expect from the efforts. When behaviours are under volitional control (as in most health behaviours), self-efficacious people will expect positive outcomes (incentives) from their efforts, whereas non-efficacious people will expect outcomes to be negative (disincentives).

<H1>What has the past 25 years told us?

Motivation is clearly a topic of growing interest in the study of diabetes self-care; a PubMed search on 18 November 2019 with the expression (Motiv*[Title/Abstract]) AND Diab*[Title/Abstract]) resulted in 3017 papers, with 115 papers published before 1990, 207 published in the 1990s, 621 published during 2000–2009, and 2074 published since 2010. In the past decades it has been recognized that motivation can be addressed at multiple levels, i.e. psychological, biological, social and environmental, and various theoretical frameworks and lines of research within each of the different levels have been developed.

<H2>Self-efficacy

Self-efficacy beliefs can develop from a variety of sources that have been explored in-depth over the past decades. Of these, enactive mastery experiences – experience of successful actions – are believed to be the most powerful ways to increase self-efficacy and most intervention studies have used goal setting [6] and are considered by some as an integral component of effective diabetes care [7]. to one's performance also play an important role in the motivation of behaviour. For example, a longitudinal observational study in people with newly diagnosed type 2 diabetes found that both self-efficacy and self-evaluation were significantly associated with dietary self-care three months later, with self-evaluation being a stronger predictor than self-efficacy [8]. Thus, it is important to recognize the difference between valid and spurious self-efficacy, with the former based on accurate self-evaluation. Bandura [3] placed self-efficacy causally as a determinant of expected outcomes, but others have shown that also can causally influence self-efficacy beliefs [9], so their relationship is reciprocal and self-reinforcing (either positively for successful outcomes or negatively for unsuccessful outcomes). Another concept that may play an important role in motivating behaviour is, which is defined as the belief that a given treatment is effective [10]. When people do not believe that their recommended treatment will help them control their weight or diabetes, they quickly lose motivation in following that treatment [11].

In addition, although Bandura [3] argued that belief about treatment effectiveness is an integral part of self-efficacy, Nouwen. [12] have shown that both self-efficacy and beliefs about treatment effectiveness are independently associated with dietary self-care behaviours. It was further shown that these behaviours may interact with each other such that each is more powerful in the presence of the other. Again, it is important to recognize the difference between self-efficacy to perform an action and self-efficacy to obtain a desired outcome, with the former only one ingredient in the latter. Self-efficacy has been widely accepted as a determinant of motivation and self-care behaviours in people with diabetes and obesity. A recent systematic review and meta-analysis of 739 cross-sectional research reports showed that self-efficacy was consistently associated with all self-care behaviours including dietary self-care, which in turn was the variable associated most strongly with HbA [13].

<H2>Self-determination theory

Self-determination theory has offered – and still offers – a comprehensive approach to motivation. Figure 1 represents a causal diagram to illustrate the theory’s variables, causal paths and interactions (see Ryan and Deci [5] for more information about this theory).

This model suggests that it is not only the of motivation that is important, but also the of motivation. Being ‘highly motivated’ does not necessarily lead to positive outcomes, especially in the long-term [14]. If motivation is (controlled) rather than (autonomous), i.e. if the motivational processes are based in ‘I have to’ instead of ‘I want to’ thoughts, it is an effortful type of self-regulation that will work only as long as the source of the motivation – typically coercion or contingent external reward – is maintained. One of two things usually happen in that scenario: (1) the person may terminate the healthy behaviours once the motivational source is no longer present; or (2) the person fails in the effort and gets feedback that competence is lacking, resulting in a termination of effort [15].

The antecedents in the model represent the treatment factors (i.e. the input of healthcare providers) which trigger the ‘mechanisms of action’ that transmit the effect of the treatment on the outcome [16]; the path of ‘good motivational treatment’ is represented in bold across the upper part of Fig. 1, while the path of ‘poor motivational treatment’ is represented across the lower part. Self-determination theory predicts that ‘good motivational treatment’ will satisfy the basic psychological requirements for expending effort: autonomy (sense of ownership, perceived choice), competence (mastery, self-efficacy) and relatedness (feeling accepted, connected). The external source of controlled motivation may drive one’s behaviour while the reward is perceived as meaningful and available, but it takes a toll on our resources – our behaviour is effortful. On the other hand, internal autonomous motivation, as part of who we are, is inherently meaningful; thus, we take pleasure in fulfilling our motives – our behaviour is effortless. Consequently, behaviours are more likely be sustained when driven by autonomous motivation, things you do just for the sake of doing them, a ‘do it for the fun of doing it’ mind set [17].

Self-determination theory includes the concept of perceived competence, a measure of individual aptitude and capacity closely related to self-efficacy [18]. Other studies have compared aspects of social cognitive theory, notably self-efficacy, with those of the self-determination model. A cross-sectional study [14] found that self-efficacy was a stronger predictor of dietary self-care in people with diabetes, whereas autonomy was a stronger predictor of satisfaction. These results were confirmed in a longitudinal study [8].

From the above, it follows that the use of fear (e.g. threat of complications) to motivate people to carry out treatment recommendations can only work temporarily because the self-care behaviours will carried out because of external rather than internal reasons. Moreover, if the negative consequences of not carrying out the self-care behaviours only become manifest far into the future, the fear will wear off quickly. From a self-efficacy theory perspective [3], however, fear may have a positive impact on self-care behaviours if it raises the sense of urgency for enhancing self-efficacy. If, on the other hand, the fear message does not include information how to avoid the negative outcome, or undermines self-efficacy beliefs the exercise of inducing fear will be futile.

The social cognitive and self-determination theories of motivation have sparked a large volume of research papers on diabetes. Most clinicians now use goal setting, and problem-solving in interventions aimed at helping people with diabetes improve self-care. Moreover, many healthcare providers also aim to provide autonomy support to help people become more independent in the management of their diabetes.

<H2>Neuro-cognitive mechanisms of appetite control

It is important to note that food, especially that high in sugar or fat, is a potent motivator in and by itself, and often competes with efforts to follow a healthy diet. This motivation for immediate gratification tends to compete with motivation to follow a healthier diet necessary to maintain or lose weight, and prevent future micro- and macrovascular comorbidities in diabetes. Dietary restriction of high-calorie foods can lead to feelings of deprivation and cravings, increasing not only the disposition and incentive to eat, but also the amount of food consumed [19]. Therefore, understanding the neuro-cognitive mechanisms underlying food motivation and appetite control, which involves cortical processing of nutritional states and food reward value, seems particularly relevant to the study of motivation to follow a healthy diet in diabetes because of the adverse effects diabetes and obesity have on the structure and functioning of the brain.

<H2>Cortical network of dietary behaviour and motivation

Dietary behaviour involves a complex and layered cortical network of motivation, reward and cognitive control [20]. Within this network there are various internal inhibitory, excitatory and feedback pathways and loops involved in executing and regulating dietary behaviours. Although specific functions can be attributed to the brain areas of this network, these structures with their specific functions work inside a dynamic network, and diminished volume or functioning of one particular structure does not necessarily result in poor functioning as other regions may compensate. Thus, alteration in dietary behaviour is never the result of a single region or function failing, rather it is the result of a complex interplay between structures within the brain network.

The of this dietary behaviour network is where input from the periphery, such as feelings of hunger, smell or taste, is first processed cognitively in this network. Involved in this are regions such as the hypothalamus and ventral tegmental area/subthalamic nucleus, the amygdala–hippocampus complex, and the insula. These regions are involved in (emotional) memory, and mental processing and evaluation of emotions, taste and smell. In the, after this initial more basic emotional processing, the insula, orbitofrontal and ventromedial prefrontal cortices are activated for the of the input and in feelings of reward. This evaluation occurs on an emotional level and is less strongly involved in controlling dietary behaviour. The striatum, a set of subcortical structures involved in many different functions, is involved in action and executing choices. The is the layer of cognitive control, namely controlling dietary behaviours executed and inhibiting responses if necessary. Structures involved in these functions are located in the prefrontal cortices.

Structural grey matter alterations within all three layers of this neural network of dietary behaviour and motivation have been observed in people with obesity or type 2 diabetes across the life-span in comparison with healthy controls [21,22]. Functionally, it has been demonstrated that activity in response to looking at food pictures in areas of the of the network was higher in obese and type 2 diabetes individuals relative to controls [23,24]. Activity of regions within this generated by the reception of gustatory food cues was lower in these groups compared with controls [25]. Interestingly, one study showed reduced perfusion in regions after a meal in obese participants, suggesting less active cognitive control [26].

<H2>Evidence for executive function involvement in control of dietary behaviour

The prefrontal brain regions involving the dorsolateral prefrontal cortex, inferior frontal cortex and the anterior cingulate cortex mediate a set of executive functions including inhibitory control, working memory and cognitive flexibility/set-shifting [27]. is the ability to inhibit a pre-potent response, such as the temptation to eat a tasty food. People with high impulsivity/weak inhibitory control are more likely to overeat [28] and be overweight/obese [29]. Other research has demonstrated that when inhibitory control is low, eating behaviour is more strongly guided by impulsivity [30]. Those with better inhibitory control show a smaller intention–behaviour gap than those with poorer inhibitory control for both dietary behaviour and physical activity [31].

, the second of the three core executive functions, is a person’s ability to keep information active and in mind, as well as the ability to manipulate this information [27]. Important components of working memory relevant to self-regulation of health behaviour include the ability to hold in mind information stored in long-term memory (e.g. health goals) and to maintain focused attention on currently active information while preventing interference from other potentially distracting information (e.g. tempting foods) [32]. Working memory capacity has been shown to moderate impulsive processes in predicting health behaviours. In people with low working memory capacity, compared with those with high working memory capacity, impulsive processes are better predictors of high energy-dense food consumption [33]. Better working memory has also been associated with greater intake of less energy-dense food such as fruits and vegetables [34]. Although inhibitory control may play a key role in an individual's ability to resist tempting foods, working memory may enable a person to consume healthier foods by maintaining health goals active in mind.

(often termed cognitive flexibility), a person's ability to switch tasks or goals when the current task/goal is no longer optimal, may facilitate both means-shifting and goal-shifting [32]. Means-shifting allows a person to find an alternative way to reach their goal (e.g. do a home workout if they miss their gym class), whereas goal-shifting allows a person to shift goals instead (e.g. not work out at all if they miss their gym class). Studies have found that set-shifting ability is related to better self-regulation of food consumption and physical activity [35].

MRI studies have shown that the above-mentioned frontal regions are indeed involved in dietary behaviour. For example, the dorsolateral part of the prefrontal gyrus was more activated when looking at food pictures in healthy weight participants who place more value on weight [36], or who achieved weight loss during a diet [37]. This region, together with the inferior frontal cortex was also more activated when suppressing the desire for tasty foods [38]. Increased prefrontal activation in people exposed to the smell of chocolate was related to lower chocolate intake afterwards [39]. Conversely, higher activity in the caudate nucleus and frontal pole regions, involved in craving and reward instead of cognitive control, was related to more chocolate intake in this exposed group [39]. Motivation is rarely studied in this context, but one study showed that young adult women without diabetes who were successful, compared with those unsuccessful in regulating their dietary behaviour had more intrinsic and autonomous reasons, and showed more motivation for self-regulation [40]. Neuroanatomically, those successful women showed more activity in the inferior frontal cortex compared with their less successful counterparts when looking at food pictures.

Studies of self-control and motivation in obesity and type 2 diabetes are scarce, although one in type 2 diabetes suggests a link between better dietary self-care and cerebral activity [41]. Of note, the relationship between diet and cognition/executive function is likely to be bidirectional. Whereas cognitive capabilities influence ability to maintain a healthy diet, consumption of a Western diet has been shown to negatively affect cognition [42], which may contribute to a vicious cycle of impaired cognition, poorer food intake, weight gain and type 2 diabetes.

<H1>Environmental factors

A person’s motivation to engage in a healthy or unhealthy lifestyle behaviour is influenced by environmental characteristics [43]. models conceptualize behaviour as a function of several layers of influence [44]. The various types and sizes of environments at different levels have been structured in the Analysis Grid for Environments Linked to Obesity (ANGELO) framework that was developed two decades ago [45]. The framework categorizes ‘obesogenic’ environmental influences into four types: physical (what is available), economic (what is the price), political (what are the rules) and sociocultural (what are the norms). These types are considered at various sizes: from macro (more distant; e.g. laws, policy), meso (reachable; e.g., neighbourhood environment) to micro levels of influence (individual’s immediate surroundings and characteristics; e.g. family and healthcare provider influences). Environments contain cues that may trigger motivations and barriers or facilitators that can hinder or enable motivations to action [46]. Such environmental characteristics are often referred to as of health behaviour and health outcomes, which are considered to be downstream consequences [47]. Current environments in advanced economies are characterized by an abundant availability of high-energy foods and infrastructures in which sedentary behaviour is easy and a default behaviour. A recent systematic literature review specifically focusing on physical environmental factors showed that lower diabetes risk and prevalence was observed in neighbourhoods that were greener, more urban and had higher walkability [48]. Studies on the influence on diabetes-related behaviours at the political and economic–environmental level are more recent and mostly concern taxation of sugar-sweetened beverages [49].

<H1>Translation of evidence to practice

<H2>Application of social cognitive theory

Most effort to use self-efficacy in behaviour change interventions has used as a core element [S2]. Having explicit goals by which to establish outcome expectancies and self-evaluate behavioural success is necessary. Collaborative goal setting by people with diabetes and their healthcare providers can help identify realistic goals that have good response efficacy. Studies have shown that collaborative goal setting of people with diabetes and their healthcare provider resulted in perceptions of increased self-management competency and increased trust in the physician, which in turn resulted in better diabetes control [S3]. An example of goal setting for dietary self-care include a study by Glasgow. [S4] who developed a brief office-based dietary intervention study in a primary care setting. After agreeing to a dietary goal, participants were then asked how the goal would be implemented and how they would deal with possible impediments (problem-solving). Problem-solving helps people with diabetes to deal with barriers to achieving their goals [S2]. Compared with a care-as-usual group, the intervention group showed modest changes in food intake of cholesterol at the 3-month follow-up, which were maintained at the 12-month follow-up.

<H2>Applying self-determination theory

The self-determination theory model suggests that healthcare professionals can help people with diabetes enhance their perceived competence (i.e. self-efficacy) by providing. Autonomy support refers to the extent to which providers elicit and acknowledge the perspectives of the person with diabetes, support their initiatives, offer choice about treatment options, and provide relevant information while minimizing pressure and control. Autonomy support can be implemented by strategies that focus on the person with diabetes making their own choices about what to do after carefully considering their own feelings and values as well as the available options. Thus, a clinician might provide information about the likely outcomes of various behaviours without providing pressure to do one of those behaviours. The clinician would make a specific recommendation based on his/her best judgement to the person with diabetes, who would then consider the pros and cons of each behaviour from their own perspective, and the practitioner would support that process. When a person with diabetes makes a choice, the clinician would respect the choice, asking only if he or she could revisit the issue in a future appointment to see how that has gone for him/her.

Supporting one's autonomy is one of the suggested mechanism of actions proposed by both self-determination theory and motivational interviewing [S7]. Prospective [S8] and randomized controlled trial (RCT) [S9] studies tested this hypothesis in people with diabetes (= 128 and 159, respectively). Both studies measured autonomy support perception, autonomous (I want to) and controlled (I have to) motivations, behavioural (self-management actions) and glycaemic control (HbA) variables. Analysis confirmed the prediction of the self-determination theory; when healthcare providers are perceived as autonomy-supportive, persons with diabetes become better motivated to self-regulate their glycaemic control actions and will, as a result, show HbA improvements.

Motivational interviewing is an evidence-based practice that has been applied successfully in diabetes [S10] with a meta-analysis showing that motivational interviewing interventions are linked to better short-term (< 6 months) diabetes self-management and decreased HbA levels [S10]. These results were confirmed by another meta-analysis of studies conducted in mainland China [S11]. Albeit these results demonstrate the efficacy of motivational interviewing, motivational interviewing is an advanced technique, requiring specific training to increase the likelihood of desired outcomes. In a network meta-analysis, Pillay. [S12] showed that the contact time of these interventions should be > 10 h and delivered by clinical psychologists in order to maximize glycaemic control benefits.

<H2>Approaches that address the neuronal network and self-regulation

Weight-loss interventions have effects on functional connections. A study in 18 obese women showed that after a 4-week caloric restriction diet, activation in reaction to looking at food pictures decreased in more reward-related areas such as the amygdala and increased in more control-related regions such as the prefrontal cortex [S13]. Furthermore, after bariatric surgery in 10 postmenopausal women, a similar decrease was seen in the caudate nucleus and Rolandic operculum when looking at food pictures, and in the insula when receiving gustatory food cues [S14]. Acute administration of glucagon-like peptide 1 (GLP-1), an intestine hormone, in type 2 diabetes and obesity resulted in changes in activity towards levels of found in healthy lean controls, in the insula, amygdala and orbitofrontal when viewing pictures of food or receiving chocolate milk [24,S15]. A similar pattern of activity alterations in similar regions was seen during treatment with GLP-1 compared with insulin glargine in type 2 diabetes [25,S16]. Thus, with GLP-1, activity within areas of the first and second layers of the dietary behaviour network became more similar to that of healthy controls, suggesting a normalization of altered brain activation.

Behavioural research has examined whether training executive functions can increase ability to self-regulate health behaviour. Reviews of have found significant reductions in food choices/intake and alcohol consumption. Larger effects were found in those already motivated to control their food intake [S17]. The majority of studies in these reviews were in healthy populations or heavy drinkers. A recent review identified only two studies that had examined the effect of on diet [S18], and both found significant reductions in food intake in overweight participants [S19,S20]. Further, in one study, reduced energy intake was found only in highly motivated participants [S20]. A recent RCT of working memory training in people with type 2 diabetes found reduce fat intake only in a subset of participants, namely those who were motivated to restrain their food intake [S21]. We are not aware of any research examining the effect of cognitive flexibility/set-shifting training on health behaviours.

Importantly, this research suggests that increasing cognitive capabilities via training or pharmacological intervention may enable motivated individuals to translate their motivation into action, and to initiate and maintain a healthy lifestyle. It also has implications for our broader understanding of the role of motivation in leading a healthy lifestyle. Specifically, it suggests that motivation alone is often not sufficient to enact a behaviour, but that the cognitive capability to do so is also needed.

<H2>Approaches that address upstream determinants

As highlighted previously, upstream factors such as characteristics in the physical, economic, political and sociocultural environments can influence individual-level factors such as motivation, and so influence behaviours and health outcomes further downstream [47]. These factors can be addressed in practice – although rarely in practice. Individuals with type 2 diabetes across the world are constantly seduced, challenged or even manipulated by food and other industries, and have access to an abundance of places to sit and eat. These motivation-undermining characteristics cannot be resolved with a single intervention but there are examples of approaches with impact. For instance, taxation has emerged as an apparent effective intervention to reduce consumption of sugar-sweetened beverages and the associated burden from chronic diseases such as type 2 diabetes and diabetes-related complications [S22]. Built environmental characteristics related to higher diabetes risk/prevalence may be addressed by urban planners when (re)designing new residential areas. In particular, this includes securing a high walkability environment and sufficient access to green space [48], and ensuring proper access to healthy and affordable foods [S23].

<H1>Future research

Studies on motivation in relation to self-control in individuals with type 2 diabetes are scarce, and warrant further investigation. The many factors that shape and can sustainably change motivations require more study, especially longitudinal studies with longer follow-up. In parallel, strategies to alter motivations by targeting upstream determinants such as environmental characteristics should be tested and evaluated.

Environmental strategies may form part of a comprehensive package of solutions to changing behaviour regardless of motivational levels [S24]. Across various types of environments there are recent advances that address the 'causes of the causes' by targeting environmental factors [47]. Increasing prices of unhealthy foods and/or subsidising healthier foods and drinks is an effective behavioural economic approach that is potentially scalable and can be imposed by policies [49,S25,S26]. encompasses subtle environmental changes that facilitate people to make desired choices, without punishing the alternatives or changing economic incentives [S27]. This strategy, also coined as, has great potential to influence dietary behaviours and physical activity [S28–S30], and is accepted by the public [S31].

<H1>Conclusions

In this paper, we reviewed the socio-cognitive, cognitive neuroscience and environmental aspects of motivation and self-regulation regarding dietary self-care in people with diabetes and obesity. Overall, the literature indicates that motivation for healthy eating is strongly related to a person's self-efficacy to initiate and maintain such a diet, and a health climate that supports autonomous choices and behaviours. Specific interventions promoting dietary self-efficacy such as goal setting and problem-solving, and a health climate that favours and supports autonomous motivation such as motivational interviewing have shown to be efficacious and effective. However, the effects of these interventions, which are now used widely in diabetes self-management interventions were modest. Long-term follow-up studies are needed.

Both neurological and behavioural research shows that the brain plays a key role in the ability to self-regulate health behaviours. Obesity and type 2 diabetes are associated with brain alteration in key areas of the dietary behaviour network responsible for emotional evaluation of food, making and executing decisions about dietary behaviour, and controlling and inhibiting these decisions, which are likely to undermine motivation to self-regulate. An important limitation of these studies is that most are underpowered and only perform region-of-interest based analyses, i.e. they a priori select several brain regions, where inhibitory structures are usually not included. Weight loss itself can reduce cognitive deficits, as can brain stimulation and pharmacological interventions. Behavioural evidence has also found that training executive functions can increase self-regulatory control, but thus far appears to be more effective in those already motivated to control their behaviour. Research on how motivation interacts with the brain in relation to dietary behaviour in obesity and type 2 diabetes is currently absent.

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Competing interests

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References

1 Maslow AH. A theory of human motivation. *Psychol Review* 1943; **50**: 370–396.

2 Vroom, VH. *Work and Motivation*. New York: Wiley, 1964.

3 Bandura A. *Self-Efficacy: The Exercise of Control*. New York: Freeman, 1997.

4 Bandura A. *Social Foundations of Thought and Action: A Social Cognitive Theory*. Englewood Cliffs, NJ: Prentice-Hall, 1986.

5 Ryan RM, Deci EL. Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *Am Psychol* 2000; **55**: 68–78.

6 Michie S, Abraham C, Whittington C, McAteer J, Gupta S. Effective techniques in healthy eating and physical activity interventions: a meta-regression. *Health Psychol* 2009; **28**: 690–701.

7 Miller CK, Bauman J. Goal setting: an integrative component of effective diabetes care. *Curr Diab Rep* 2014; **14**: 509.

8 Nouwen A, Ford T, Balan AT, Twisk J, Ruggiero L, White D. Longitudinal motivational predictors of dietary self-care and diabetes control in adults with newly diagnosed type 2 diabetes mellitus. *Health Psychol* 2011; **30**: 771–779.

9 Williams DM. Outcome expectancy and self-efficacy: theoretical implications of an unresolved contradiction. *Pers Soc Psychol Rev* 2010; **14**: 417–425.

10 Rogers RW. Cognitive and physiological processes in fear appeals and attitude change: a revised theory of protection motivation. In: Cacioppo JT and Petty RE (eds), *Social Psychophysiology*. New York: Guildford Press, 1983; 153–176.

11 Polonsky WH, Skinner TC. Perceived treatment efficacy: an overlooked opportunity in diabetes care. *Clin Diabetes* 2010; **28**: 89–92.

12 Nouwen A, Urquhart Law G, Hussain S, McGovern S, Napier H. Comparison of the role of self-efficacy and illness representations in relation to dietary self-care and diabetes distress in adolescents with type 1 diabetes. *Psychol Health* 2009; **24**: 1071–1084.

13 Brown SA, García AA, Brown A, Becker BJ, Conn VS, Ramírez G *et al*. Biobehavioral determinants of glycemic control in type 2 diabetes: A systematic review and meta-analysis. *Patient Educ Couns* 2016; **99**: 1558–1567.

14 Williams GC, Patrick H, Niemiec CP, Williams LK, Divine G, Lafata JE *et al*. Reducing the health risks of diabetes: how self-determination theory may help improve medication adherence and quality of life. *Diabetes Educ* 2009; **35**: 484–492.

15 Paul-Ebhohimhen V, Avenell A. Systematic review of the use of financial incentives in treatments for obesity and overweight. *Obes Rev* 2008; **9**: 355–367.

16 Pearl J. Interpretation and identification of causal mediation. *Psychol Methods* 2014; **19**: 459–481.

17 Teixeira PJ, Silva MN, Mata J, Palmeira AL, Markland D. Motivation, self-determination, and long-term weight control. *Int J Behav Nutr Phys Act* 2012; **9**: 22.

18 Williams GC, Freedman ZR, Deci EL. Supporting autonomy to motivate patients with diabetes for glucose control. *Diabetes Care* 1998; **21**: 1644–1651.

19 Yannakoulia M. Eating behavior among type 2 diabetic patients: a poorly recognized aspect in a poorly controlled disease. *Rev Diabet Stud* 2006; **3**: 11–16.

20 Neseliler S, Han JE, Dagher A. The use of functional magnetic resonance imaging in the study of appetite and obesity. In: Harris RBS (ed.), *Appetite and Food Intake: Central Control*. Boca Raton, FL: CRS Press, 2017; ?–??.

21 Willette AA, Kapogiannis D. Does the brain shrink as the waist expands? *Ageing Res Rev* 2015; **20**: 86–97.

22 Moulton C, Costafreda S, Horton P, Ismail K, Fu CY. Meta-analyses of structural regional cerebral effects in type 1 and type 2 diabetes. *Brain Imaging Behav* 2015; **9**: 651–662.

23 Pursey KM, Stanwell P, Callister RJ, Brain K, Collins CE, Burrows TL. Neural responses to visual food cues according to weight status: a systematic review of functional magnetic resonance imaging studies. *Front Nutr* 2014. doi: 10.3389/fnut.2014.00007

24 van Bloemendaal L, IJzerman RG, ten Kulve JS, Barkhof F, Konrad RJ, Drent ML *et al*. GLP-1 receptor activation modulates appetite- and reward-related brain areas in humans. *Diabetes* 2014; **63**: 4186–4196.

25 ten Kulve JS, Veltman DJ, van Bloemendaal L, Groot PFC, Ruhé HG, Barkhof F *et al*. Endogenous GLP-1 and GLP-1 analogue alter CNS responses to palatable food consumption. *J Endorcinol* 2016; 229: 1N12.

26 Nguyen Trung Le DS, Chen K, Pannacciulli N, Gluck M, Reiman EM, Krakoff J. Reanalysis of the obesity-related attenuation in the left dorsolateral prefrontal cortex response to a satiating meal using gyral regions-of-interest. *J Am Coll Nutr* 2009; **28**: 667–673.

27 Diamond A. Executive functions. *Ann Rev Clin Psychol* 2013; **64**: 135–168.

28 Guerrieri R, Nederkoorn C, Schrooten M, Martijn C, Jansen A. Inducing impulsivity leads high and low restrained eaters into overeating, whereas current dieters stick to their diet. *Appetite* 2009; **53**: 93–100.

29 Nederkoorn C, Jansen E, Mulkens S, Jansen A. Impulsivity predicts treatment outcome in obese children. *Behav Res Ther* 2007; **45**: 1071–1075.

30 Hofmann W, Rauch W. Gawronski B. And deplete us not into temptation: Automatic attitudes, dietary restraint, and self-regulatory resources as determinants of eating behavior. *J Exp Soc Psychol* 2007; **43**: 497–504.

31 Hall PA, Fong GT, Epp LJ, Elias LJ. Executive function moderates the intention-behavior link for physical activity and dietary behavior. *Psychol Health* 2008; **23**: 309–326.

32 Dohle S, Diel K, Hofmann W. Executive functions and the self-regulation of eating behavior: a review. *Appetite* 2018; **124**: 4–9.

33 Hofmann W, Gschwendner T, Friese M, Wiers RW, Schmitt M. Working memory capacity and self-regulatory behavior: toward an individual differences perspective on behavior determination by automatic versus controlled processes. *J Pers Soc Psychol* 2008; **95**: 962–977.

34 Whitelock V, Nouwen A, van den Akker O, Higgs S. The role of working memory sub-components in food choice and dieting success. *Appetite* 2018; **124**: 24–32.

35 Kelly SM, Updegraff JA. Substituting activities mediates the effect of cognitive flexibility on physical activity: a daily diary study. *J Behav Med* 2017; **40**: 669–674.

36 Smeets PAM, Kroese FM, Evers C, de Ridder DTD. Allured or alarmed: counteractive control responses to food temptations in the brain. *Behav Brain Res* 2013; **248**: 41–45.

37 Jensen CD, Kirwan CB. Functional brain response to food images in successful adolescent weight losers compared with normal-weight and overweight controls. *Obesity* 2015; **23**: 630–636.

38 Giuliani NR, Mann T, Tomiyama AJ, Berkman ET. Neural systems underlying the reappraisal of personally craved foods. *J Cogn Neurosci* 2014; **26**: 1390–1402.

39 Frankort A, Roefs A, Siep N, Roebroeck A, Havermans R, Jansen A. Neural predictors of chocolate intake following chocolate exposure. *Appetite* 2015; **87**: 98–107.

40 Lopez RB, Milyavskaya M, Hofmann W, Heatherton TF. Motivational and neural correlates of self-control of eating: a combined neuroimaging and experience sampling study in dieting female college students. *Appetite* 2016; **103**: 192–199.

41 Chechlacz M, Rotshtein P, Klamer S, Porubská K, Higgs S, Booth D *et al*. Diabetes dietary management alters responses to food pictures in brain regions associated with motivation and emotion: a functional magnetic resonance imaging study. *Diabetologia* 2009; **52**: 524.

42 Davidson TL, Jones S, Roy M, Stevenson RJ. The cognitive control of eating and body weight: It's more than what you 'think'. *Front Psychol* 2019; **10**: 62.

43 Ball K, Timperio AF, Crawford DA. Understanding environmental influences on nutrition and physical activity behaviors: where should we look and what should we count? *Int J Behav Nutr Phys Act* 2006; **3**: 33.

44 Bronfenbrenner U. Experimental toward an ecology of human development. *Am Psychol* 1977; **32**: 513–531.

45 Swinburn B, Egger G, Raza F. Dissecting obesogenic environments: the development and application of a framework for identifying and prioritizing environmental interventions for obesity. *Prev Med* 1999; **29**: 563–570.

46 Pinho MGM, Mackenbach JD, Charreire H, Oppert JM, Bárdos H, Glonti K, Rutter H *et al*. Exploring the relationship between perceived barriers to healthy eating and dietary behaviours in European adults. *Eur J Nutr* 2018; **57**: 1761–1770.

47 Lakerveld J, Mackenbach J. The upstream determinants of adult obesity. *Obes Facts* 2017; **10**: 216–222.

48 den Braver NR, Lakerveld J, Rutters F, Schoonmade LJ, Brug J, Beulens JWJ. Built environmental characteristics and diabetes: a systematic review and meta-analysis. *BMC Med* 2018; **16**: 12.

49 Backholer K, Sacks G, Cameron AJ. Food and beverage price promotions: an untapped policy target for improving population diets and health. *Curr Nutr Rep* 2019; **8**: 250–255.

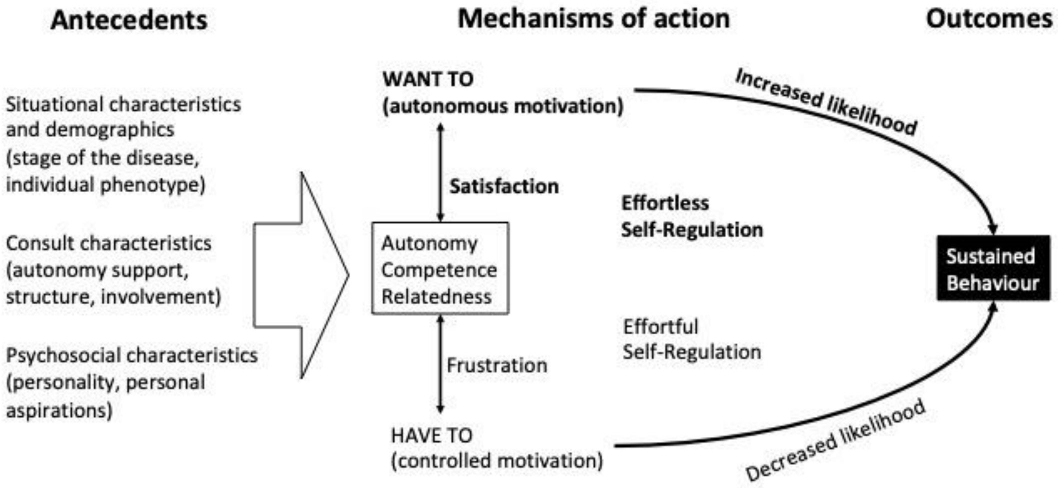
50 Tang TS, Brown MB, Funnell MM, Anderson RM. Social support, quality of life, and self-care behaviors among African Americans with type 2 diabetes. *Diabetes Educ* 2008; **2**: 266– 276.

FIGURE 1 Representation of self-determination theory applied to the context of healthy behaviour sustainability. Based on Teixeira *et al*. [S32] and Santos *et al*. [S33].

Supporting Information

Additional Supporting Information may be found in the online version of this article:

Doc. S1 Additional references ([S1–S35]).


Antecedents
Mechanisms of action
Outcomes
Situational characteristics and demographics (stage of the disease, individual phenotype)
Consult characteristics (autonomy support, structure, involvement)
Psychosocial characteristics (personality, personal aspirations)
WANT TO (autonomous motivation)
Satisfaction
Autonomy
Competence
Relatedness
Frustration
HAVE TO (controlled motivation)
Effortless Self-Regulation
Effortful Self-Regulation
Increased likelihood
Decreased likelihood
Sustained Behaviour